Arnold Schwarzenegger
Governor

ENERGY SYSTEMS INTEGRATION AREA OF THE PIER PROGRAM DISTRIBUTION RESEARCH ASSESSMENT

PIER FINAL PROJECT REPORT

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Distribution Research Assessment

Final Report

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The format, outline, and type-of-content included follow a framework that was developed for the California Energy Commission by Navigant Consulting, Inc. in the Distributed Energy Resources (DER) & Transmission programs.

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Preface

This report presents S&C Electric Company's findings and observations related to distribution research and development for the Energy Systems Integration Area of the California Energy Commission Public Interest Energy Research (PIER) Program. Comments or questions on any aspect of this report including both the high level observations and the project details should be addressed to:

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Executive Summary

The provision of reliable and affordable electricity for California depends on a robust electric system. There has been considerable focus on assuring adequate transmission and generation in the state, but a reliable, efficient and safe distribution system is also critical. As California's economy continues to expand and grow, the current distribution system, like other utility systems, will need to be flexible and responsive locally to a wide range of contingencies.

The Energy Systems Integration area of the California Energy Commission's Public Interest Energy Research (PIER) Program is developing a distribution research plan. The distribution system is collectively more than five times the size of the transmission system and thus requires greater maintenance. Nearly all customers are connected to the distribution system while very few are connected directly to the transmission system. As a result, the distribution system is responsible for approximately 95% of customer outages. Regulatory jurisdiction of the distribution system lies entirely within the state.

The new Distribution Research and Development (R&D) Assessment will focus on enabling technologies that will support state goals for integrating efficiency, demand response, and renewable and nonrenewable distributed generation technologies into distribution planning and operations. This new initiative area will coordinate closely with other existing Commission R&D programs. As the Distribution R&D Assessment was developed, three focus areas were identified in which research initiatives could be categorized (Figure ES-1).

Figure ES-1: Focus Area Summary

Focus Area	Component Optimization	System Integration	Markets Mechanisms
Sub-Areas	• New Components • Optimal Ratings • Proactive Diagnostics	• Automation & Self-Healing • Open Architecture for Communications • Distribution Design for Enabling DER • Real-Time Operating Information • Enhanced Planning Tools • Preparation for Distribution of the Future	• Business Models to Support Distribution Modernization
Research Initiatives	15	14	4

The Distribution R&D Assessment began with a preliminary literature search of multiple sources to identify existing and planned research activities in the private and public sectors. Additional input was obtained through an interview process with Investor Owned Utility (IOU) representatives in California and other states, industry sources, equipment manufacturers, research coalition representatives, government agencies, and industry consultants regarding efforts in distribution R&D. A comprehensive list of all research projects that were examined as part of this assessment has also been included in the appendices.

Each research initiative was characterized for its state of technology development and for the impact/timing of achieving the objectives of the research initiatives. The four states of technology development are research, development, demonstration and commercialization. The Impact-Timing framework includes four levels (Figure ES-2).

Figure ES-2: Impact-Timing Framework

Level	Description
Base	Although essential to today's business these technologies represent the common denominator in performance and cost
Key	These technologies are important for performance and cost advantages for today's industry players
Pacing	Although they are not fully embodied in current products, they may, if successfully applied, have a substantial impact on the performance and cost profile in the reasonably near future
Emerging	These technologies may have a large impact on the performance and cost profile in the future but this is far from certain

Note: There is a normal progression from the Emerging technology level to the Base technology level as technologies become developed and more widely applied. Source: DER Integration Assessment

A gap analysis was performed to determine if there were significant, moderate, or little/no gap in a particular research area.

Upon completion of the analysis the following preliminary observations were drawn:

- There are critical gaps in distribution R&D.
- Distribution has a large installed base and utilizes mature technology.
- Most of the existing R&D focuses on improving cost performance and service reliability through incremental improvements.
- Manufacturers developing new products generally respond to specific customer requests or undertake projects despite significant market risk, since distribution technologies and the associated R&D are expensive and take a long time to reach significant sales in the market. Generally, such R&D remains unknown while in development.

- R&D projects not undertaken by manufacturers (or not yet known about from the manufacturers) are predominately undertaken as consortium efforts (e.g. Electric Power Research Institute- EPRI).
- Consortium projects tend to focus on near-term deliverables; few are concentrating on revolutionary concepts.
- Most of the R&D is still performed in North America or in some cases by overseas companies but still initially targeting the North American market. In some specific technology areas, International utilities are leading the deployment with demonstrations or commercialization.

Chapter 1: Introduction

California's distribution system is collectively more than five times the size of the transmission system and thus requires greater maintenance. Nearly all customers are connected to the distribution system while very few are connected directly to the transmission system. As a result, the distribution system is responsible for approximately 95% of customer outages. Distribution outages often are caused by environmental factors such as trees, birds, and squirrels which do not have the same impacts on the robust transmission level.

The electric power industry has been undergoing fundamental changes as a direct result of state and federal regulation. The unbundling of vertically integrated electric utilities has presented a variety of opportunities and challenges. The distribution sector is perhaps the least affected from a regulatory standpoint. It continues to be a regulated entity and will be into the foreseeable future. The challenges the distribution sector faces include aged infrastructure that is, for the most part, based on fifty-year-old technology, a large amount of equipment in place serving load, and very limited data to use in the operation of the system.

Beyond these challenges, California IOUs are now required to include significantly higher levels of energy efficiency, demand response, and renewable and nonrenewable generation into their systems. As implementation of these new state policies progress, utilities will be required to integrate and incorporate new technologies and strategies into their systems and planning processes.

California utilities are confronted with changing load characteristics. With more customers having high-tech computer equipment and electronics, their desire for greater power quality has increased. With the impact of these and other non-linear loads on the distribution system the utilities must address power quality and reliability issues. At this time the direct correlation between customers desired electric power services, what they actually need, and services they are presently receiving, has yet to be satisfactorily determined. Further exploration is warranted to quantify levels of service with direct association between reliability, power quality, and value.

These challenges are creating gaps between the capabilities of the system in place today and the changing nature of the load it must serve in the future. At the same time, developments in electric power delivery technology may hold the keys to solving some of the problems facing the distribution system. All of this requires a fresh analysis of the distribution landscape to identify key challenges appropriate for public interest research. The guiding question for the distribution research program is:

> *Are there research, development, demonstration or commercialization opportunities that will improve distribution system adequacy, efficiency,*

flexibility, reliability and cost while integrating DER into operations and planning?

In California, as well as in service areas of other utilities, distributed generation (renewable and nonrenewable), demand response, energy efficiency are all considered Distributed Energy Resources (DER) opportunities. For the purposes of this report, energy storage close to the point of energy consumption will also be included as a DER resource.

The Energy Systems Integration (ESI) area of the Energy Commission's PIER program is developing its Distribution Research plan organized within the following Focus Areas:

- <u>Component Optimization</u> - Hardware in the distribution system of the future will be comprised of existing control and operating equipment plus equipment housed in conventional enclosures that have advanced functionality. Enhanced durability of these systems will facilitate improved reliability and efficiency of the distribution system.
- <u>System Integration</u> - While proven automation technology exists, additional functionality will lead to individualized levels of service and power quality. Customer located technology and advanced DG will require interactive capabilities of equipment, new skills, and simulation & analysis tools to aid decision-making and operation of the distribution system of the future.
- <u>Market Mechanisms</u> - Clarification of the financial drivers and their impacts are needed to initiate a broad application of technologies. DER can be used to benefit central generation fleet, transmission congestion, and distribution overloads. Automation of distribution can enable distribution to be operated more efficiently and reliably, and with faster restoration times after outages. An overall business case based on the contributions may reveal a credible investment proposal.

A major step in the research plan development process is to understand current research being conducted by industry, nonprofit organizations, equipment manufacturers and government; and to identify where gaps exist. This Distribution R&D Assessment is a reflection of past and present activities and represents a "bottom up" survey of research activities. Information collected through research, interviews, and interaction with stakeholders will help identify appropriate potential PIER program activities. This information, along with an evaluation of what research is appropriate for a public interest R&D program, will support PIER in developing a plan and solicitations to support those activities.

Background Research and Interviews

The S&C team investigated distribution R&D in progress and planned in two broad areas. The initial effort concentrated on a web-based search of activities at national labs and universities. They also looked for related International R&D. This approach helped identify significant issues that are being pursued statewide, nationally, and internationally.

The team then conducted phone and face-to-face interviews with research laboratories, Department of Energy (DOE), manufacturers, and utilities in California and other parts of North America. This produced an extensive-list of R&D projects and programs both in-progress and planned for the near future.

On the international front the team was able to identify interesting R&D focusing on of the widespread use of renewable energy resources within the distribution system. Also promising are the environmentally-friendly solutions to hardware and maintenance issues. International technologies and successes should be continually monitored for status and results. (See Appendix E)

Background on Private Sector R&D

Most of the development of new technologies to improve or modernize operation of the distribution system is being done by manufacturers in the private sector. Utilities have been focused on cost-cutting. Since utilities are in a capital-intensive industry, have extensive infrastructure that is relatively low-tech, and have little regulatory incentive to adopt new technology, cost-cutting provides short-term return at understood risk. Their initiatives to develop features, functionality, and new technologies are usually compelled by many factors including:

- A customer defining a need and committing to purchase based upon successful development.
- Anticipation that unique functionality added to an existing product would provide increased market share.
- A mechanism to reduce cost or increase product life to exceed technology offered by the competition.
- Achieve operational efficiencies.
- Respond to new regulatory mandates or drivers like:
    - Tax credits (i.e., spurring wind generation impacting technology for dynamic VAR support).
    - Reliability mandates (driving technologies to avoid outages or reduce the length of outage).
- Challenges to secure right-of-way.
- Lack of space for construction which drives a smaller footprint.

- Pressures to accomplish more with few people/reduced expertise (get data and feedback remotely).
- Power factor correction mandates.
- Environmental and minimal maintenance factors which are location specific.
- Protection schemes and safety (i.e., avoid closing into a fault).

North American companies are doing the bulk of private sector distribution system R&D. The research is usually done in the form of incremental change to an existing product line. Development time is extremely long and expensive, so market entry can be difficult. Also, little is done on step-change research for distribution because of the backward compatibility the new product has to have with existing product and infrastructure. Entities like IEEE Power Engineering Society provide a mechanism for utilities, manufactures and academics to define standards that ensure industry agreement, product compatibility, and adaptability to existing systems. Some interoperability developments are being done by manufacturers, which, again, is usually customer-specified and customer-funded.

Finally, private companies are not forthcoming regarding their developments since they lose or gain competitive advantage by their ability to bring differentiated features, functions and benefits to the market place. Given the dynamic in which technology development specifics are not available, only general information about manufacturing activity can be provided. Most of the manufacturing activity is oriented toward development rather than research since the addition of features and functionality provide competitive advantage and increased sales.

Private sector advances in R&D are moving towards the inclusion of automation, intelligence, reliability, and efficiency. The following are a few of the areas of development by private sector:

- Geographic Information Systems (GIS). Applications are in development to utilize the platform for more efficient planning, engineering design, and developing targeted maintenance efforts. GIS is also being integrated with automated meter reading data and call center data to more quickly identify fault locations and more efficiently dispatch for power restoration.

- Automated Meter Reading (AMR). The data from ARM may be consolidated from various acquisition systems to reduce the integration challenges for utilities.

- Manufacturers are also working on mobile computing for use in field. Development of more rugged hardware, increased interoperability, enhanced security-features, and applications that further increase leverage of the existing software and hardware.

- The distribution system includes millions of points that hold potential for telemetry. Some of the telemetry needs are real-time while others are occasional. Manufacturers are working on secure, cost effective communications; usually associated with a particular application such as automated switching which utilizes proprietary protocols.

- Further development of electronic devices which when applied to traditional equipment provides more sophisticated control as well as the capability to integrate remote information.

- Greater functionality and interoperability in recloser & relay technologies. New developments include the use manufacturer battery-free device that can be controlled with a PDA, as well as distribution switches and reclosers which interoperate with substation relays. Relays are also being further developed to use light to initiate and mitigate the impacts from arc-flash and improve safety conditions and include scrambler functionality for increased security and time-stamping for synchronous phasing.

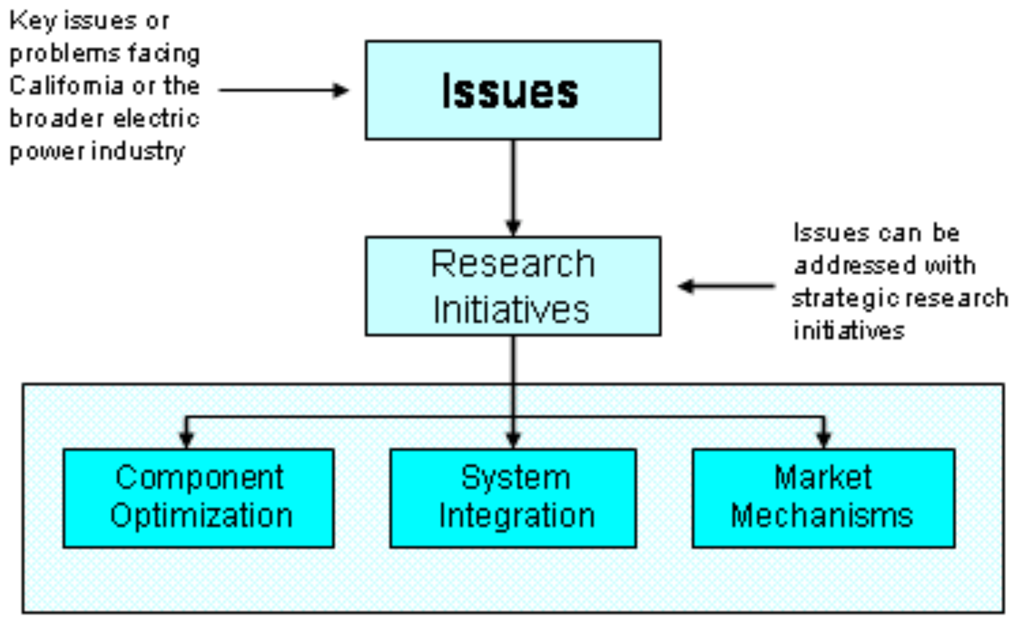
New concepts are usually customer-driven and need responsive development times. Product enhancements are typically implemented to address field-problems. This is a high reliability business and equipment needs to last for 30 or more years. The cost to take a new product through R&D is approximately between five and ten million dollars. Typical product R&D is about two to three years.

Manufacturers usually announce new product developments at industry tradeshows such as the IEEE Transmission and Distribution show and Distributech. New developments are kept confidential until companies are prepared to take them to market. Another place to identify new developments is in the industry trade magazines. It can take as long as ten years to educate the marketplace to the point where they are readily purchasing the product after introduction. (See Appendix C for additional description.)

Framework of Analysis

In parallel with, and incorporating the information gathered from the background research and interviews, a framework was utilized for assessing the status of the distribution R&D efforts (Figure 1-1).

Figure 1-1: Taxonomy of Analysis Framework



The range of issues and challenges facing California utilities and the broader electric power industry were identified (e.g. *replacing underground cable*). It was determined these issues can be addressed with strategic research initiatives (e.g. *addressing the aging infrastructure*). The assessment places the initiatives into focus areas that more clearly support the research initiatives and issues. Chapter 2 explores the process by which the issues were identified and elaborates on the research initiatives that address those issues.

An overview of representative research projects most applicable to the research objectives of the Energy Commission's ESI area is presented in Chapter 3. Equipped with the issues, research initiatives, and project information, the level and concentration of activities are mapped out and potential areas where funding might be warranted are thus discussed in Chapter 4. Inclusion of the elements stated thus far opens the way for a more effective discussion among the various stakeholders involved with distribution systems.

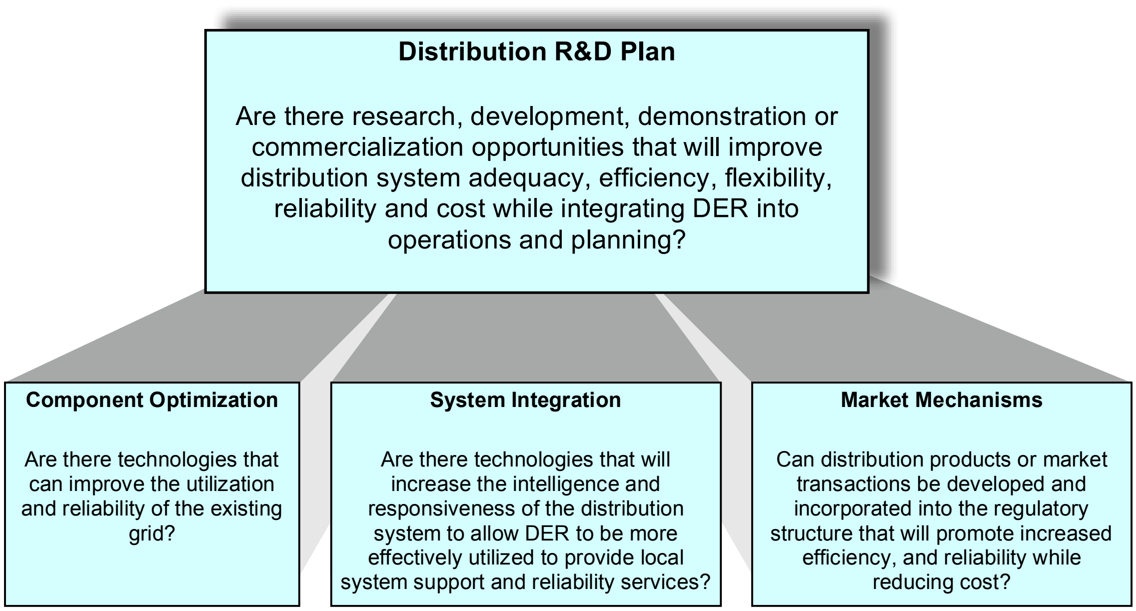
Chapter 2: Issues and Research Initiatives

The results of the literature search and the interviews provided essential inputs to isolate issues facing electric power distribution and the research initiatives to address these issues. In the interviews, non-California IOU representatives, equipment industry sources, research coalition representatives, industry consultants, non-profit organizations, and government provided information on their visions for distribution, where key obstacles exist, where their distribution efforts are focused, and the expected outcome for such efforts. The background research and existing projects identified painted a picture of what "is" the current state of research and development.

Issues - Identification

Information obtained from the initial interviews and assessment was gathered and examined for common themes and key insights. This process revealed numerous issues and activities within the distribution space that are aimed at addressing a variety of current and future challenges. The issues are identified here in the form of critical questions and arranged along the lines of the three focus areas: Component Optimization, System Integration, and Market Mechanisms (Figure 2-1).

Figure 2-1: Distribution Issues Analysis



Research Initiatives

Current and proposed efforts to address the issues were identified during the interview process and formed the basis of the research initiatives identified. The research initiatives address the issues in the three focus areas of Component Optimization, System Integration, and Market Mechanisms.

Component Optimization

We identified 15 research initiatives within three sub-areas in the Component Optimization focus area. These sub-areas include New Components, Optimal Ratings, and Proactive Diagnostics (Figure 2-2).

Figure 2-2: Issues and Research Initiatives – Component Optimization

Component Optimization	
Issues	Research Initiatives
Are there technologies that will reduce costs, improve reliability and efficiency of the distribution system?	**New Distribution Components** ▪ Improve fault interrupting devices that will enhance reliability and power quality ▪ Develop miniaturized equipment that will reduce space requirements on the customer's premise to provide electric service and reduce costs ▪ Utilize solid state devices that will improve reliability and power quality ▪ Improve transformer design that will increases efficiency and reduces spare transformer inventory costs ▪ Accelerate superconductor research to gain related high efficiencies for power delivery and reduce space needed for electric infrastructure ▪ Employ new connection techniques that will improve reliability and reduce skill levels needed to make connections ▪ Apply new underground structures that will be more durable thus reducing cost and improving reliability

Component Optimization	
Issues	Research Initiatives
Are there operational capabilities that will enhance the loading capabilities of the legacy distribution system?	**Optimal Ratings** ▪ Deploy temperature sensing to monitor the performance of critical system components ▪ Develop technologies that calculate real-time line ratings to allow accurate monitoring of the equipment
Can equipment problems be detected prior to them causing a service interruption? Can faults be located more quickly?	**Proactive Diagnostics** ▪ Improve ability to monitor system conditions in order to predict component failures and act preemptively ▪ Assess underground cable diagnostic techniques and determine more accurate and cost effective methods ▪ Initiate equipment self-reporting that identifies problems and their locations thus improving reliability and reducing cost ▪ Develop new technologies and techniques to install/repair underground cable less invasively ▪ Develop instrumentation that locates faults more quickly to improve reliability ▪ Improve waveform analysis and expand signature library to make fault detection more effective

The following projects related to Component Optimization are existing R&D projects that help illustrate approaches being pursued to optimize components:

- **Cable Diagnostic Focused Initiative (DOE):** This project provides extensive research with both short-term and long-term based results, which address cable diagnostic technologies, and techniques that will facilitate planned cable replacement programs to improve reliability.
- **Condition Monitoring and Maintenance Strategies for In-Service Non-Ceramic Insulators, Underground Cables and Transformers (PSERC):** This project developed electrical discharge recognition methods to identify failing insulators and underground cables.

- **Distributed Fiber Optic Temperature Sensor (EPRI):** With the ampacity information based on precise Distributed Fiber Optic-measured temperatures, existing circuits can be used more heavily and more wisely, in many cases deferring costly upgrading projects.
- **Development and Field Trial of a Solid State Current Limiter (EPRI):** The Solid State Current Limiter will reduce equipment damage, reduce repair costs and improve reliability.

System Integration

In the System Integration focus area, we identified 14 research initiatives within six sub-areas. These sub-areas include Automation & Self-Healing, Open Architecture for Communications, Distribution Designs for Enabling DER, Real-Time Operating Information, Enhanced Planning Tools, and Preparation for Distribution of the Future (Figure 2-3).

Figure 2-3: Issues and Research Initiatives – System Integration

System Integration	
Issues	Research Initiatives
How can interoperability between both new and legacy system components be achieved?	**Automation and Self-Healing** ▪ Define and develop information exchanges (e.g. distributed intelligent agents for distribution control) that will enhance grid operations and improve reliability. ▪ Define and develop enhanced communications (e.g. mesh networks) and controls that will make possible data exchange rates required to operate new and legacy systems
What changes must be made to the distribution system to accommodate future load?	**Open Architecture for Communications** ▪ Promote the development of open standards that will facilitate the integration of intelligent equipment and data communication networks.

System Integration	
Issues	Research Initiatives
Are there new applications for DER that will provide operational benefits and system support? **Note that DER refers to: Distributed Generation, Demand Response, and/or Storage technologies.*	**Distribution Design for Enabling DER** ▪ Further evaluate distribution system support/operational benefits ▪ Demonstrate distribution technologies that will support the economic viability and the efficient integration of mobile DG into the distribution system. ▪ Create advanced C&C devices for DER that reduces response and restoration time while improving operational efficiencies of the distribution system ▪ Evaluate storage technologies that will augment DER supply sources to maximize the utilization of the power delivery infrastructure ▪ Quantify the value of residential DER to the distribution system
What is needed to operate the distribution system in real-time?	**Real-Time Operating Information** ▪ Develop advanced technologies that will monitor, relay, and analyze information in real-time to improve operating decisions and reliability ▪ Establish new skill sets for Human Factors
Can the system benefits of DER, automation, and other emerging technologies be valued and included in utility Distribution Planning?	**Enhanced Planning Tools** ▪ Develop more sophisticated analysis software ▪ Develop methods to improve data integrity
What non-technical issues are likely to impact the distribution system of the future?	**Preparation for Distribution of the Future** ▪ Analyze how extensive automation will impact utility operations and procedures ▪ Develop training techniques and simulators to facilitate transition

The following projects related to Systems Integration are existing R&D projects that help illustrate approaches being pursued by other entities:

- **IntelliGrid Consortium (EPRI):** This consortium is looking to advance the use of automation and intelligent equipment in the distribution setting.

- **Advanced Distribution Automation Initiative (EPRI):** The ADA™ Initiative will be coordinated with other R&D programs in advanced distribution system concepts such as transformers and sensors. This effort is being coordinated with DOE, manufacturers, and multiple utilities.

- **Developing Low-Cost Sensor Networks for Advanced Distribution Automation (EPRI):** Improve operations and support migration to ADA with advanced sensors and monitoring networks that provide real-time, system wide monitoring.
- **Distributed Intelligent Agents for Decision Making at Local Distributed Energy Resource Levels (DOE):** This project will develop uniform interface capabilities between the customer load control systems and the utility in order to optimize the performance of the power delivery system during peak load conditions.

- **Electric System Automation Philosophy (NEETRAC):** This project will develop a comprehensive checklist of items that should be considered when planning the transition from a legacy distribution system to an automated system. Use of the checklist will reduce costs, speed deployment and improve system functionality of the final product.

- **Potential Applications for Sensor Networks in Power Delivery (NEETRAC):** This project will identify existing sensor network systems that can be economically deployed in the near future to enhance reliability, improve system functionality and reduce costs.

Market Mechanisms

In the Market Mechanisms focus area; we identified 4 research initiatives within the Business Models to Support Distribution Modernization sub-area (Figure 2-5).

Figure 2-4: Issues and Research Initiatives – Market Mechanisms

Market Mechanisms	
Issues	Research Initiatives
Are the business cases for Automation and DER well understood?	**Business Models to Support Distribution Modernization** ▪ Assess the value of automation ▪ Develop business cases based on current practices that address utility investment in automation, DER, and system upgrades. ▪ Explore cost-effective measures of system upgrades ▪ Examine differentiation of reliability service levels and power quality for pricing

The following is an example of an existing project related to Market Mechanisms:

- **Develop Economical Strategies for Managing Aging Underground Distribution Cables (EPRI):** This project will develop processes to identify the most economic strategies for dealing with testing, repair, and replacement of underground cables.

Chapter 3: Distribution R&D Landscape

The preliminary literature search yielded 103 existing distribution R&D projects. This chapter presents an overview of a subset of those projects. It also describes the parties who are performing and sponsoring the research, and the general nature of R&D in the distribution arena. A technology assessment framework is also presented that was used to analyze transmission R&D activities in a previous study. The analysis grouped the R&D activities according to stage of development and competitive impact. A complete listing of the projects is presented in the appendices.

Industry and Stakeholder Overview

The distribution sector holds a unique position within the electric power industry in that it is the element that connects the customer. It is the "vital link" to the customer that delivers the end use product. There are key stakeholders with interests in distribution that continue to shape the nature of the physical system, as well as the distribution business.

Owners – In today's industry structure, the electric distribution system is owned and operated by the incumbent electric utility and continues to be a regulated entity. The utilities are responsible for the maintenance and capitalization of the distribution system, and generate revenue through regulated tariffs. The primary concern for operators is system reliability, often referred to as "keeping the lights on". Other concerns for the utilities include a strong rate base, cost efficiency, and maintaining a stable system.

Customers – Customers have a stake in the distribution sector because it is their interface to the total electric system. They depend on it to deliver the power consistently with good quality. The level of reliability and power quality desired varies from customer class to customer class and customer to customer. Residential customers may be able to tolerate an occasional service interruption and voltage dip, but commercial and industrial customers cannot endure any variation in the power that is delivered. The consequences of deviations result in such a monetary impact that these end-users can justify the expense of power quality and standby power equipment. Many industrial and commercial customers' equipment requires reliable, high quality power services. Customers would like to receive premium services at the best price possible.

Regulators – In most areas of the U.S., the electric distribution system is under the regulatory jurisdiction of a state Public Utility Commission. The regulators are a balance to the natural monopolies that exist in distribution, and generally focus on the commercial side of distribution, including pricing and service requirements. They are also playing a central role in altering the business models of the entire electric power industry as many states around the country deregulate their electricity markets.

Manufacturers – This sector includes the companies that produce distribution equipment, as well as those who design and support the integration of new systems and devices that are used to monitor and control the system. This sector has traditionally taken the lead in performing R&D for new distribution system products.

R&D Activity Overview

Research and development activities in the distribution segment of the electric industry are accomplished in a variety of areas. The distribution element is the largest in the overall electric system. It is five times the size of the transmission system. It is also the most dynamic in terms of growth, maintenance, and change. These characteristics drive a high demand for new equipment. Due to this demand, manufacturers are in a position to not only manufacture the needed equipment, but also be significant contributors in the area of development and demonstration for new products.

The majority of innovation and new products come from the efforts of the equipment manufacturers. This is because they are well situated to accumulate knowledge on a national level about the challenges facing the industry. Their understanding of the issues combined with manufacturing capabilities that can be upgraded affords them the opportunity to make significant strides in developing new products and services to fill the needs of the industry. These companies are generally not inclined to disclose R&D activities that can be classified as emerging research for strategic competitive positioning reasons. For that reason, R&D being conducted by the manufacturers is not included in this assessment.

Like the transmission segment of the industry, relative lack of competition, a history of risk aversion and conservatism, industry maturity, and other factors have created a situation where a portion of the research is carried out by collaborative research organizations that are funded by multiple public or private sources, thereby sharing the risks and the potential rewards. Noteworthy examples of these are the Department of Energy (DOE), Electric Power Research Institute (EPRI), the Consortium for Electric Reliability Technology Solutions (CERTS), National Renewable Energy Laboratory (NREL), and the National Electric Energy Testing and Research Center (NEETRAC). Other parties including electric utilities, equipment manufacturers, and national laboratories are also involved in distribution R&D.

Some R&D is being done at various universities. Examples include University of California- Irvine, Henry Samuel School of Engineering Advanced Power and Energy Program (APEP), Michigan State University, Texas A&M University, University of Illinois Electrical Engineering Power and Energy Systems, and Georgia Tech. The focus of most of this work is in the development of software tools to model and analyze the electric distribution system.

Funding for the collaborative R&D organizations comes from industry and the public sector, with the Department of Energy, utilities, and the California Energy Commission providing significant resources.

Activity within Focus Areas

The California IOU's own distribution R&D programs and engineering/operations functions provided input that resulted in some of the initiatives in the assessment. They range from conceptual ideas to programs currently in place.

The majority of the initiatives identified in the Component Optimization focus area are for the sub-area, New Distribution Components, and it should be noted that many of the initiatives in this sub-area were areas of concern for the IOU's. This can be explained by the fact that individual component development is generally done by the manufacturers. Therefore, it is not an effort that is undertaken in the collaborative arena. These initiatives suggest that the manufacturers are not meeting some of the California IOU's needs. There is some thought and attention being given to the sub-area of Optimal Ratings for distribution equipment by the California IOU's. This area has not received much attention at the national level.

Initiatives in the sub-area Proactive Diagnostics demonstrate the need for tools and techniques to sustain the legacy distribution systems. This is a concern with most all the electric utilities in North America including the California IOU's. In addition, this same idea of proactive diagnostics will probably become a central element of the distribution system of the future.

A preponderance of initiatives identified in the System Integration focus area are centered on Distribution Design for Enabling DER. This opportunity has the attention of most of the utilities in North America. A lot of R&D is in progress in the collaborative areas such as EPRI, NYSERDA, NEETRAC, and DOE. Most of the initiatives included for further analysis in this assessment came from the California IOU's. The Automation & Self-Healing sub-area contain issues that also have significant attention on a national level. There have been many successes in the area of automation and self-healing. However, many challenges face the equipment manufacturers including collaboration in creating definitions for broad standards. The term automation is the standard bearer to define the capabilities for the distribution system of the future.

Real-time information from the distribution system is a critical need to better operate the system. The majority of systems today are radial circuits with little or no information coming to a central control center. As a result, system operation is done manually with personnel in radio-dispatched vehicles. Data from the circuits, similar to what is available on the transmission system, plus remotely controlled switching equipment will result in an operating environment that is much more responsive to disturbances on the system.

There are also some needs expressed by the California IOU's to improve the capabilities of responding to interruptions the way the existing system is configured today. The distribution utilities will have to operate a large part of the legacy system into the future without the benefit of new technology. These initiatives are concentrated on tools to significantly improve the current operating procedures to provide a higher level of service to the customers. In addition, these tools will enhance system operations when the existing system is populated with new, automated equipment.

The orderly application of DER to the distribution system leads to additional initiatives in the System Integration focus area. The development of software analysis tools is being done in collaborative fashion at both EPRI and DOE. Some thoughts on empirical validation of DER impact analysis tools came from the California IOU's. A combination of the fact that the distribution system is large, with operating and configuration data integrity being questionable, validation drives the need to perform field tests to confirm the analysis used to predict the impact of DER. The utilities acknowledged that the work presently being done to promote the development of open architecture for communications that facilitate the use of intelligent distribution equipment showed promise for future applications.

The last sub-area consideration, Preparation for Distribution of the Future, is on secondary aspects that extensive distribution automation will have on the public, utility workers and regulators. The Energy Commission staff and California IOU generated these topics. It appears that California is the first to address this matter. The attention of the manufacturers and most all of the utilities in North America is on extending their existing distribution systems and adopting new, economically sound technologies to improve performance. There has been little or no thought given to the long-range impacts that the distribution system of the future will have on society.

The Market Mechanisms focus area starts at the heart-of-the-matter with the sub-area of Business Models to Support Distribution Modernization. The initiatives in Business Models explore the value propositions for distribution automation and DER resource deployments within the overall business operations of the IOUs. A solid foundation of customer-expectations for service quality and reliability must be established and agreed upon between IOUs, policy-makers, and ratepayers. Part of this initiative will evaluate the relationships between service-levels and pricing.

Two aspects of the IOUs obligatory side of the value proposition will also be analyzed as part of this business model initiative; the cost of providing benefits from system upgrades (including DER) as well as exploring new alternatives for cost-effectiveness with these upgrades.

These types of analysis may have been performed case-by-case or piecemeal and probably remain proprietary to each utility. Very little public or collaborative research activities on business models were identified. The objective of this research is to bring transparency to the business modeling and common foundation amongst and between the IOUs and policy-makers.

This business-related R&D and later business-related initiatives will help assure that the more technical R&D initiatives as part of the over-arching objectives of the Energy Policy and Loading Order are pulled-through based on demand rather then stalling in commercialization stage of technology development.

Framework for Analyzing Activity

To determine the focus of current research, we determined the issues and research initiatives being addressed by each project or project category. To gain further insight into the nature of this research and technology development, the projects were also analyzed by their stage of technology development and their competitive impact.

Technology generally follows a natural progression along the technology development chain, which consists of four stages: research, development, demonstration, and commercialization (Figure 3-1).

Figure 3-1: Technology Development Process

Research	Development	Demonstration			Commercialization	
		Initial System Prototypes	Refined Prototypes	Commercial Prototypes	Market Entry	Market Penetration
• General assessment of market needs • Assess general magnitude of economics • Concept and Bench testing • Basic research and sciences (e.g., materials science)	• Research on component technologies • Development and initial of product offering • Pilot testing	• Integrate component technologies • Initial system prototype for debugging • Demonstrate basic functionality	• Ongoing development to reduce costs or for other needed improvements • "Technology" (systems) demonstrations • Some small-scale "commercial" demonstrations	• "Commercial" demonstration • Full size system in "commercial" operating environment • Communicate program results to early adopters/ selected niches	• Initial commercial orders • Early movers or niche segments • Product reputation is initially established • Business concept implemented • Market support usually needed to address high cost production	• Follow-up orders based on need and product reputation • Broad(er) market penetration • Infrastructure developed • Full-scale manufacturing

The impact-timing framework describes how important a technology is to performance and cost among industry players. Impact timing is extrinsic with respect to the technology, and closely related to the industry in which the technology is applied. The framework comprises four levels (Figure 3-2).

Figure 3-2: Impact-Timing Framework

Level	Description
Base	Although essential to today's business these technologies represent the common denominator in performance and cost
Key	These technologies are important for performance and cost advantages for today's industry players
Pacing	Although they are not fully embodied in current products, they may, if successfully applied, have a substantial impact on the performance and cost profile in the reasonably near future
Emerging	These technologies may have a large impact on the performance and cost profile in the future but this is far from certain

Note: There is a normal progression from the Emerging technology level to the Base technology level as technologies become developed and more widely applied.

Examining the intrinsic (technology development stage) and extrinsic (impact-timing) characteristics of a technology provides a useful framework for determining which technologies should be pursued, the appropriate level of investment, and the timing for that investment. Technical risk varies along the technology development chain; the highest risk associated with research. Market or adoption risk varies along the level of impact timing; the highest risk is with emerging technologies. Rewards do not vary according to where the technology is on the technology development chain; however, emerging technologies generally offer greater rewards than base technologies.

Therefore, research activities in emerging technologies tend to have the greatest technical/market risk and the greatest reward. Commercial, base technologies have the lowest market/technical risk and the lowest reward. For emerging commercial technologies, there is little technical risk, but high market risk and high rewards.

Chapter 4: Gaps in R&D Activity

Approach

In this chapter, gaps are identified for each of the research initiatives discussed in Chapter 2, based on the projects presented in Chapter 3. Gaps are defined as disparities between the current level of private/public activity and the required level of activity to ensure a strategy has a reasonable chance for success at resolving the issue it is addressing.

The research initiatives were first plotted by their position on the technology development scale (research, development, demonstration and/or commercialization) and the impact-timing scale (base, key, pacing or emerging). Interviews with researchers and company representatives working on these research initiatives provided the baseline information for assessing gaps. The magnitude of the gap for each research initiative is based on the amount and thoroughness of the research pursuing a particular initiative. Figure 4-1 presents the framework that was used.

Figure 4-1: Research Gap Descriptions

Designation	Description
Significant Gap	Few companies or entities are adequately pursuing this strategy at a level that will likely ensure the strategy has a reasonable chance of success to help resolve the issue it is addressing. This could indicate an area that has been overlooked or just emerging as a viable research initiative. However, it may be an initiative that is not appropriate or feasible to pursue at this time.
Moderate Gap	Continued and additional activity is likely required to ensure the research has a reasonable chance of success to help resolve the issue it is addressing.
Little or No Gap	Little additional work beyond what is currently funded is necessary. There are many companies and/or entities pursuing this initiative. The current level of activity is likely appropriate to ensure the strategy has a reasonable chance of success to help resolve the issue it is addressing.

Gap Analysis by Focus Area

Component Optimization

Research initiatives in the Component Optimization focus area that were identified in the collaborative arena are aimed at making improvements to the fundamental components of the distribution system. Common themes are the desire to squeeze extra capacity out of the existing system by increasing equipment ratings, enhancing the reliability and increasing performance capability of the system to allow reductions in operating safety margins. As noted earlier in this report, there are substantial research efforts being made by the manufacturers that supply the electric distribution system industry. However, because that work is, by necessity, proprietary, it could not be included in this evaluation.

- In terms of the research initiative impact timing are two-thirds are base-key and one-third are pacing-emerging. Since manufacturers drive a lot of this activity and are short term focused, most of those initiatives with significant gaps are in the research phase of development or emerging with respect to timing.

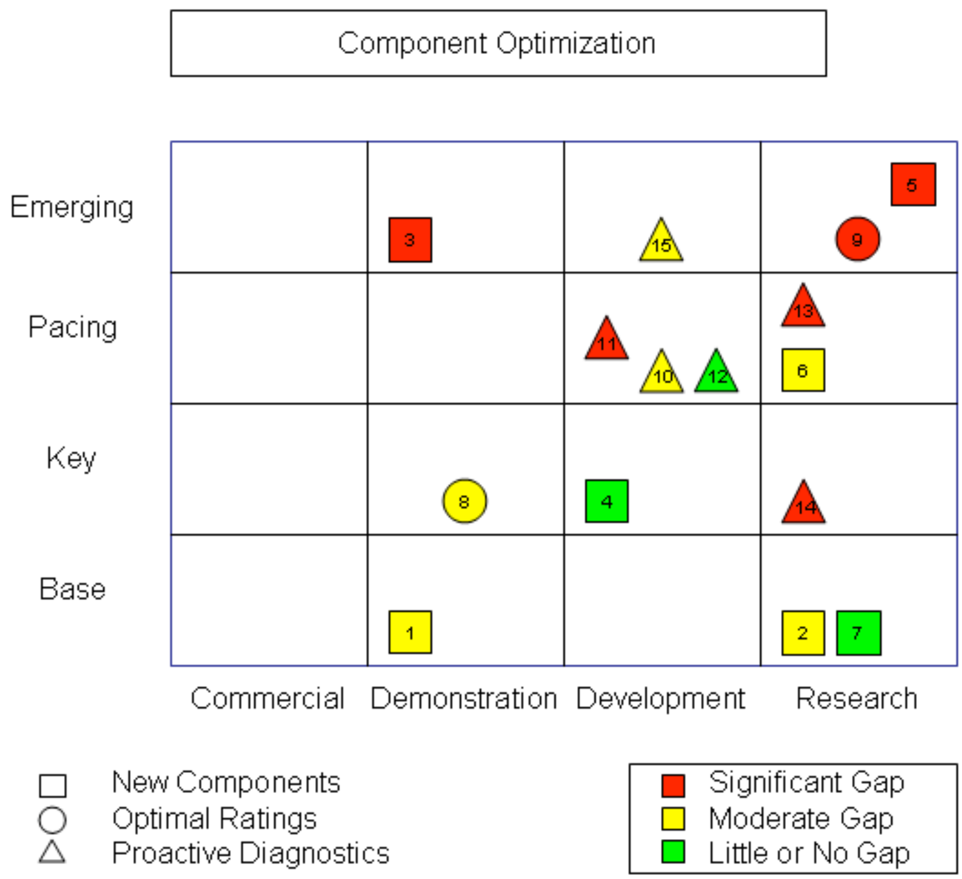
- Research initiatives are seeking to apply better information and operating techniques to increase the capacity of the system components, reduce cost, and better manage aging assets to mitigate outage impacts. In many cases the technology may not be revolutionary, but the lack of wide application may be limiting the industry's understanding and trust in the technologies.

- Some technologies such as predictive diagnostic techniques for underground cable may be developed in concept but are in need of demonstration to create awareness, develop operating experience, and ultimately reduce costs.

- Automation and mechanization that have been successfully developed in other industries have not necessarily been applied in the distribution business. Over time, such technology could enable cost savings and create a fundamental shift in the operation philosophy. There appears to be little activity in this area, in part because this is a very mature, conservative, cost-conscious industry with minimal market drivers to encourage adaptation of new and innovative technology. Component revolution is minimal; advancement is incremental and short term in nature. Manufacturers are willing, at the behest of their customers, to incorporate new functions and features into their existing product.

- Manufacturers are pursuing most of the initiatives in this focus area. The work being done is through collaborative efforts of California utilities and others in the nation. Predicting and preventing major component failures is currently at the forefront of research work. Successful development of equipment and techniques to do this will be a critical element for the distribution system of the future as well as play a key role in sustaining the existing infrastructure.

Figure 4-2: Gap Analysis – Component Optimization



Research initiatives – Component Optimization	
New Components	1. Improve fault interrupting devices that will enhance reliability and power quality 2. Develop miniaturized equipment that will reduce space requirements on the customer's premise to provide electric service and reduce costs 3. Utilize solid state devices that will improve reliability and power quality 4. Improve transformer design that will increases efficiency and reduces spare transformer inventory costs 5. Accelerate superconductor research to gain related high efficiencies for power delivery and reduce space needed for electric infrastructure 6. Employ new connection techniques that will improve reliability and reduce skill levels needed to make connections 7. Apply new underground structures that will be more durable thus reducing cost and improving reliability
Optimal Ratings	8. Deploy temperature sensing to monitor the performance of critical system components 9. Develop technologies that calculate real-time line ratings to allow accurate monitoring of the equipment
Proactive Diagnostics	10. Improve ability to monitor system conditions in order to predict component failures and act preemptively 11. Assess underground cable diagnostic techniques and determine more accurate and cost effective methods 12. Initiate equipment self-reporting that identifies problems and their locations thus improving reliability and reducing cost 13. Develop new technologies and techniques to install/repair underground cable less invasively 14. Develop instrumentation that locates faults more quickly to improve reliability 15. Improve waveform analysis and expand signature library to make fault detection more effective

System Integration

Research initiatives in the System Analysis Tools and System Operations focus area deal with automating the distribution system, positioning for the distribution system of the future while enabling distributed generation, demand response, and greater real time operations.

The distribution system currently has relatively little automation, yet the expectations are changing. Distribution systems are approaching their limits of reliability and they are being operated at greater utilization, which reduces contingency capacity. Traditionally, distribution personnel have been in a reactive mode, waiting for a customer call with information on an outage. This information is utilized to dispatch a crew to fix a fault, often taking an hour or more to locate. In the next five years 20 – 40% of the personnel in utilities will be eligible for retirement; therefore, retaining institutional knowledge from this maturing workforce is key. With an aging distribution asset base operations information to target maintenance decisions is also essential for cost effective operations in the future. While many automation technologies have been deployed (automatic meter reading, automated dispatching, remote control switching, capacitor control automation, etc.), interoperability between systems has been limited.

Ultimately, the distribution system of the future will bring these elements together and is needed for a broad based deployment of distributed resources where the fundamental distribution system design, protection, communications to devices, visibility and operational tools need to increase dramatically. The areas of DER facilitation, real-time operations and enhanced planning/analysis tools are the primary focal point for more efficient operation of the system. As the system migrates to automation, changes in system configuration, loading and performance (power factor, voltage regulation, etc.) will occur more quickly. As a result, planning the system will become more real time to support the complex operating requirements of an automated system.

Interoperability will likely start with three phase primary controlling devices and eventually incorporate customer devices/loads and delivery system intelligence. Intelligence will likely evolve to facilitate designs to serve a group of customers between two or more automated interrupting devices with sufficient capacity from either source to serve the load. This could evolve to a differentiated service option including 'zero outage' capability. Migrating to a self-healing network of this type will require improved communications and increased system diagnostics for automation assisted operations. This automation and intelligence would also facilitate distributed generation and integration, demand response, and facilitate dynamic voltage control and loss management.

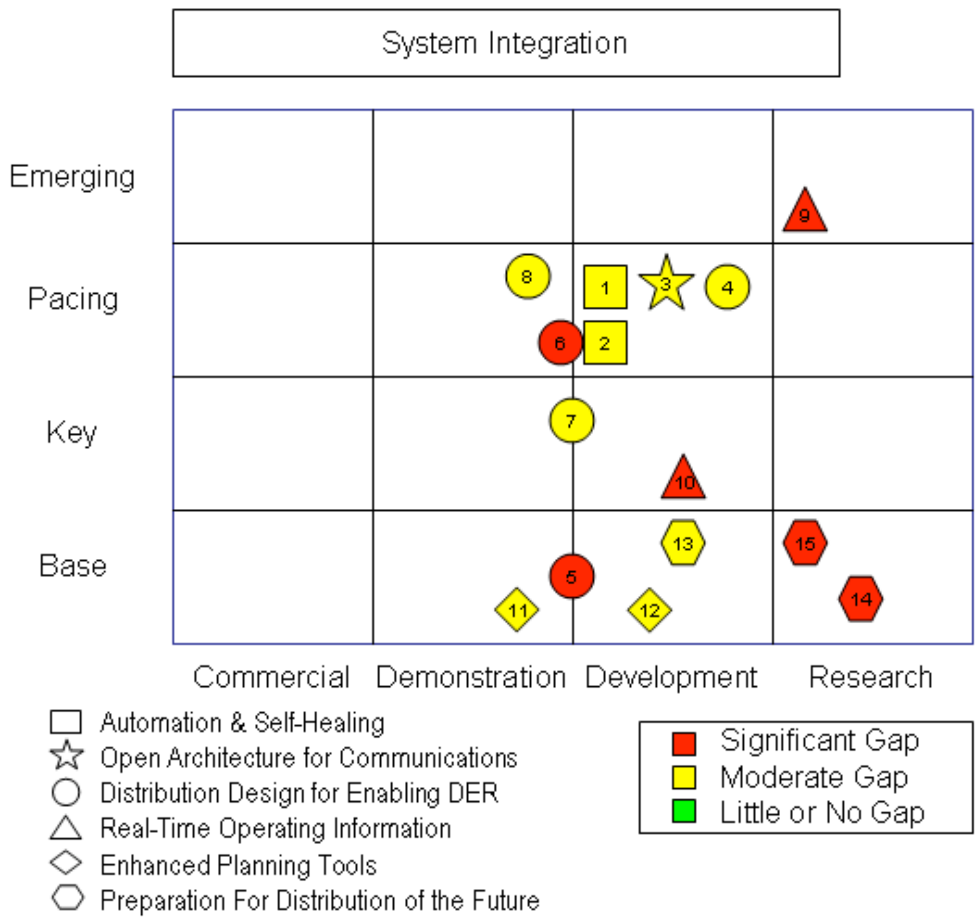
- Just over half of the research initiatives are emerging-pacing and the balance is base, with two in key. The majority are almost all in the development-demonstration area. Because each of the issues addressed in this focus area touch almost all elements of an electric distribution system, individual manufacturers cannot undertake the development of all the components that will make a significant impact on the system. Therefore, research is accomplished through collaborative efforts of the utilities.

- The dominant issues in this focus area are overcoming the bearers to distribution automation equipment working together to realize a totally automated system. Communications and interoperability are significant issues in that the electric distribution system has many, geographically dispersed locations that need some ability to exchange information/data to and from an intelligent hub. This problem is compounded by the fact that there are many methods used for data communication (hard wire, fiber optics, wireless, satellite, etc.) The second major issue is that software is used to make equipment interact and operate in support of the automation concept. The existing software is generally proprietary to the manufacturer supplying the equipment. This barrier can only be overcome by the utilities working together to develop a common software package that will function with all equipment control systems and this be truly interoperable.

- The focus for development of electric distribution system automation has been at the component level and automating localized areas of the system. As these localized areas become more numerous, operation of the system becomes more complex. If the automation systems are not uniform in equipment and operation, the complexity is compounded. Some research is being directed at ways to develop an organized approach to automating small portions of the system such that operational complexities will be reduced and the localized areas will work together when there borders come together.

- Existing consortiums are pursuing many of these initiatives. What is lacking is a consensus on the design philosophy; overall interoperability planning and risks associated with modern distribution networks. The initiatives that PIER will consider will be selected to begin to close these gaps. These projects are in progress with broad support from utilities in California and across the nation. They are close to providing tangible results that will benefit the consumers and the utilities. The California utilities can provide the resources to be a test bed for these emerging technologies.

Figure 4-3: Gap Analysis – System Integration



Research initiatives – System Integration	
Automation and Self-Healing □	1. Define and develop information exchanges (e.g. distributed intelligent agents for distribution control) that will enhance grid operations and improve reliability. 2. Define and develop enhanced communications (e.g. mesh networks) and controls that will make possible data exchange rates required to operate new and legacy systems
Open Architecture For Communications ☆	3. Promote the development of open standards that will facilitate the integration of intelligent equipment and data communication networks.
Distribution Design For Enabling DER ○	4. Further evaluate distribution system support / operational benefits 5. Demonstrate distribution technologies that will support the economic viability and the efficient integration of mobile DG into the distribution system. 6. Create advanced C&C devices for DER that reduces response and restoration time while improving operational efficiencies of the distribution system 7. Evaluate storage technologies that will augment DER supply sources to maximize the utilization of the power delivery infrastructure 8. Quantify the value of residential DER to the distribution system
Real-Time Operating Information △	9. Develop advanced technologies that will monitor, relay, and analyze information in real-time to improve operating decisions and reliability 10. Establish new skill sets for Human Factors
Enhanced Planning Tools ◇	11. Develop more sophisticated analysis software 12. Develop methods to improve data integrity
Preparation For Distribution of the Future ⬡	13. Analyze how extensive automation will impact utility operations and procedures 14. Develop training techniques and simulators to facilitate transition

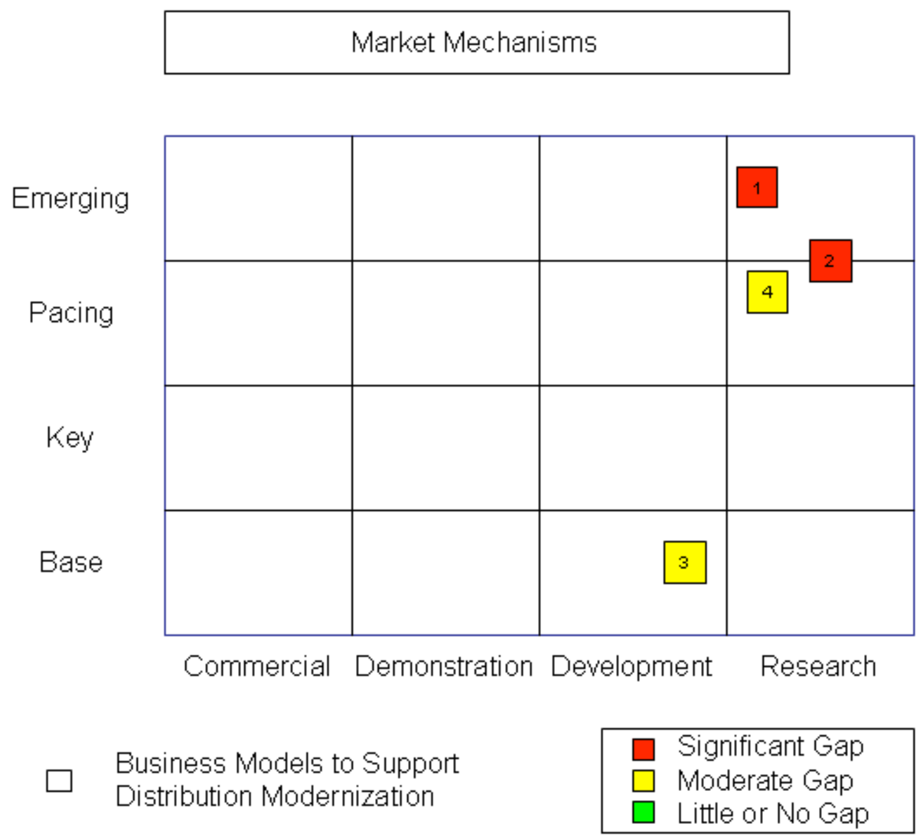
Market Mechanisms

The electric distribution function has remained a fully regulated entity, there has been little or no research directed at the Market Mechanisms focus area in the traditional sense. This study concluded that it is obvious that a fully automated electric distribution system will impact the unregulated market in the future. Therefore, there are issues that need to be studied to determine what influence advanced distribution technology will have on both the markets and society in general.

- Four research initiatives were identified by this study. They are in the emerging/pacing-research category. One is in base-development stage. Continued work in these areas is needed.

- Research work in this area is or will be non-technical in nature. The results of these efforts will direct policy development and provide sound business case analysis for deployment of fully automated electric distribution systems.

Figure 4-4: Gap Analysis – Market Mechanisms



Research initiatives – Market Mechanisms	
Business Models to Support Distribution Modernization ☐	1. Assess the value of automation 2. Develop business cases based on current practices that address utility investment in automation, DER, and system upgrades. 3. Explore cost-effective measures of system upgrades 4. Examine differentiation of reliability service levels and power quality for pricing

Chapter 5: Final Observations

Initial Assessment

- There are critical gaps in distribution R&D.
- Distribution has a large installed base and utilizes mature technology.
- Most of the R&D focuses on improving cost performance and service reliability through incremental improvements.
- Manufacturers developing new products generally respond to specific customer requests or undertake projects despite significant market risk, since distribution technologies and the associated R&D are expensive and take a long time to reach significant sales in the market. Generally, such R&D remains unknown while in development.
- R&D projects not undertaken by manufacturers (or not yet known about from the manufacturers) are predominately undertaken as consortium efforts.
- Consortium projects tend to focus on near-term deliverables; few are concentrating on new long-term concepts.
- Most of the R&D is still performed in North America or in some cases by overseas companies but still initially targeting the North American market. In some specific technology areas, international utilities are leading the deployment with demonstrations or commercialization.

Potential Drivers of Observed Activity

- This is a mature industry. The large installed base requires backward- compatibility with the inherent design and operational approach.
- Distribution as a sector is capital intensive.
- On average, the assets and personnel associated with distribution engineering and operations are aging. Reinvestment and hiring has not been pursued at the rate of depreciation and retirements.
- Real-time information and component interoperability is limited: operational response is typically based upon customer phone calls and planning done from estimated growth assumptions applied to historic peak load data.
- The inherent nature of the regulated structure limits market tendencies to apply new technologies for increased efficiency and performance. Currently, there are no, or limited-rewards for taking risk both by the IOUs and companies in the supply chain.
- The policy to utilize distributed energy resources in a meaningful way introduces a new driver for increased component interoperability and real-time distribution operation information.

Appendix A: Component Optimization Projects

The following projects have Component Optimization as their primary focus area.

1. CEC (500-03-024) ZBB Energy Corporation, Demonstration of ZBB Energy Storage System. $1,873,133 Contract Manager David Chambers. Project Completed.

2. CEC (500-98-038) OptiSwitch Technology., Light Activated Surge Protection Thyristor for Distribution System Reliability, $499,402. Project Completed.

3. CEC (700-99-010) Onsite Sycom Energy Corporation, Interconnection Requirements for Distributed Energy Resources $395,085. Project Completed.

4. CEC (500-03-009) M.Cubed, San Francisco Co-op DER Regional Solutions Project $595,647. Contract Manager, David Michel

5. CEC (500-01-043) UC Regents of California, CIEE, Demand Response Enabling Technologies WA-03-01 New Thermostat, New Temperature Mode and New Meter, Contract Manager David Michel

6. CEC (500-01-043) UC Regents of California, CIEE, Demand Response Enabling Technologies WA-04-01 California Demand Response Business Network, Contract Manager David Michel

7. CEC (500-01-043) UC Regents of California, CIEE, Demand Response Enabling Technologies WA-04-03 Network Security Architecture, Contract Manager David Michel

8. CEC (500-02-028) EPRI, Energy Storage for Transmission or Distribution Applications, $65,000, Project Completed.

9. CEC (500-03-011 #3) National Renewable Energy Laboratory, Universal Interconnect Device, $481,158, Contract Manager Bernard Treanton

10. CEC (500-02-028 #16) EPRI, Energy Storage for Transmission or Distribution (EPRI program #94) $28,400. Project Completed.

11. EPRI - ADA Intelligent Universel Transformer

12. EPRI - Characterizing Electromagnetic Compatibility of Broadband Over Powerline (BPL) Technologies (1011217)

13. EPRI - Developing Low-Cost Sensor Networks for Advanced Distribution Automation (1010605)

14. EPRI - Bushing Power Factor Testing (1006767)

15. EPRI - Distributed Fiber Optic Temperature Sensor (TO-111617)

16. EPRI - Testing for Gassing Sites in Power Transformers Using an Acoustic Emissions Technique (1001229 and 1007369)

17. EPRI - Life Evaluation of In-Service, Pipe-Type Cable Systems (111949)

18. EPRI - Development and Field Trial of a Solid State Current Limiter (1006166 and 1007303)

19. EPRI - Technology Development of Energy Storage Options for Improved T&D Asset Utilization (051557)

20. DOE - Cable Diagnostic Focused Initiative

21. DOE - Demonstrate Grid-Friendly Appliances Which Sense Grid Frequency Excursions & Provide Autonomous Reserve With Their Response

22. PSERC - Condition Monitoring and Maintenance Strategies for In-Service Non-Ceramic Insulators (NCI), Underground Cables and Transformers (T-6)

23. NYSERDA - Inverter Test Procedure Demonstration

24. ORNL (Oak Ridge National Labs) - Power Electronics Project

Appendix B: System Integration Projects

The following projects have System Integration as their primary focus area.

1. CEC (500-03-026) Lawrence Berkeley National Laboratory, Demand Response Research Center: Demand Shifting with Thermal Mass, David Michel, Mariann Piette

2. CEC (500-03-026) Lawrence Berkeley National Laboratory, Demand Response Research Center: Automated Demand Response in Commercial Buildings, David Michel, Mariann Piette

3. CEC (500-98-040) Alternative Energy Systems Consulting Inc., Intelligent Software agents for control & scheduling of DG. $554,010. Project Completed.

4. CEC (500-02-014 WA-112) Electricity Innovation Institute, CEID (now Intelligrid) Consortium for Electric Infrastructure to support a digital society, $500,000. Contract Manager Laurie ten Hope

5. CEC (500-00-016) Alternative Energy Systems Consulting, Inc. Demonstration of Intelligent Software Agents for Control & Scheduling of Distributed Generation. $844,970. Project Completed.

6. CEC (500-01-033) Distributed Utility Associates, Distributed Utility Integration Test “DUIT”. $2,049,850. Project Completed.

7. CEC (500-01-043) UC Regents of California, CIEE, Demand Response Enabling Technologies WA-00-00 Service Based Universal Application Interface for Demand Response Energy Systems, Contract Manager David Michel

8. CEC (150-99-003 #3) Lawrence Berkeley National Laboratory, CERTS Microgrid Amendment $1,115,500, Project Completed.

9. CEC (500-97-012 Edison Technology Solutions, Southern California Edison, Substation Reliability $215,000. Project completed.

10. CEC () Development of a Real-Time Monitoring Dynamic Rating System for Overhead Lines

11. CEC (500-03-011) National Renewable Energy Laboratory, Modeling Interconnection and Anti-Islanding of DER- Endecon $19,256. Contract Manager Bernard Treanton

12. CEC (500-03-024) Lawrence Berkeley National Laboratory, CERTS- Microgrid Laboratory Test Bed, Contract Manager Bernard Treanton

13. CEC (500-03-034) Distributed Utility Associates; DUIT Distributed Utility Integration Testbed, $2,976,437. Contract Manager David Michel

14. CEC (500-04-008) New Power Technologies, Verification of Optimal Methodology $5,427,726 Contract Manager, Linda Kelly.

15. CEC (500-03-011) #2, National Renewable Energy Laboratory, Modeling and Testing of Effects of Unbalanced Loading on National Voltage Regulation, DTE $309,258. Contract Manager Bernard Treanton

16. CEC (500-03-011 #5) National Renewable Energy Laboratory, Modeling Interconnection Analysis & Planning $405,487, Contract Manager Bernard Treanton

17. EPRI - Advanced Distribution Automation - ADA (1011651)

18. EPRI - ADA Advanced Distribution Communication

19. EPRI - ADA Advanced Distribution Power Engineering

20. EPRI - ADA Metering

21. EPRI - ADA Integrating Energy Sources Into Distribution Systems

22. EPRI - Improve Distribution System Performance by Optimizing Power Factor (1011003)

23. EPRI - Response of Protective Relays to Input Signals During Extreme Power System Conditions (1009164)

24. EPRI - Advanced Distribution Automation Initiative

25. EPRI - IntelliGrid Consortium

26. EPRI - CEIDS Self-Healing Grid

27. EPRI - Developing Low-Cost Sensor Networks for Advanced Distribution Automation (1010605)

28. EPRI - Power Quality Improvement Methodology for Wires Companies (051688)

29. EPRI - Cable Testing Network – ECTN (1007364 and 1008969)

30. EPRI - Distribution Fault Anticipator: Algorithm Development (1001879)
31. EPRI - Power System Load Modeling – PSLM (1011986)
32. DOE - Aggregation Through Seamless Interoperability
33. DOE - GIS Based Automated Energy Distribution & Reliability System
34. DOE - Distributed Energy Systems Certification, Testing, and Validation
35. DOE - Innovative Distributed Power Interconnection and Control System
36. DOE - Interconnection Standards Development (IEEE1547)
37. DOE - Interconnection Systems Characterization and Operational Field Testing
38. DOE - Mad River Microgrid Power System
39. DOE - Development and Deployment of Distributed Energy Systems
40. DOE - Software For Fully Integrated Thermal & Electrical Energy, Modeling Assessment, and Interoperable Control
41. DOE - Distributed Intelligent Agents for Decision Making at Local Distributed Energy Resource (DER) Levels
42. PSERC - Accurate Fault Location in Transmission and Distribution Networks Using Modeling, Simulation and Limited Field-Recorded Data (T-10)
43. NEETRAC - Potential Applications for Sensor Networks in Power Delivery
44. NEETRAC - Electric System Automation Philosophy
45. NYSERDA - Aggregating Distributed Generators
46. NYSERDA - GridCom Monitoring & Control System Demonstration
47. NYSERDA – DG Interconnection
48. CEC - Intelligent Software Agents for Control & Scheduling of Distributed Generation
49. EPRI - Develop Security for Distribution Automation and SCADA Systems (056016)
50. EPRI – ADA Planning for Integration of Energy Sources

Appendix C: Markets Mechanisms Projects

The following projects have Market Mechanisms as their primary focus area.

1. CEC (500-03-026) Lawrence Berkeley National Laboratory, Demand Response Research Center: Evaluation of RTP for Large Users, David Michel, Mariann Piette

2. CEC (500-02-014) WA-100 Electricity Innovation Institute, DER Partnership Interconnection and Market Integration, $500,000. Project Completed

3. CEC (500-01-039) New Power Technologies, Development and Demonstration of Methodology to Assess Value of DER, $616,689. Project Completed

4. CEC (500-03-011 #4) National Renewable Energy Laboratory, Innovative Ratemaking Treatment for DER-Synapse $217,258, Contract Manager Bernard Treanton

5. CEC (500-03-011 #6) National Renewable Energy Laboratory, Interconnection Grid Effects and Tariff Design for DER-Administration $181,664, Contract Manager Bernard Treanton

6. CEC (500-00-022) Gas Technology Institute, Identifying Opportunities in Distributed Generation $75,000 Project completed

7. CEC (100-98-011) EPRI- Multiple studies targeting Distributed Resources Information and Tools for Business Strategy Development, $596,250 Project(s) completed

8. CEC (500-00-02 #10) EPRI, Distributed Resources Studies continued, Business Strategies, $596,250. Project completed.

9. CEC (500-00-023 #12) EPRI, Distributed Resources Studies continued, Integration of Distributed Resources on Electric Distribution Systems $63,653. Project completed

10. CEC (500-00-023 #13) EPRI, Distributed Resources Studies continued, Using Distributed Resources to create electric distribution systems strategic advantage $44,690. Project completed

11. EPRI - Develop Economical Strategies for Managing Aging Underground Distribution Cables (1009993)

12. EPRI - Assessing the Key Drivers of Reliability for Electric Distribution Systems (1007653)

13. EPRI - Evaluation of Web-Based Cost-Effective Power Quality Monitoring System (1009514)

14. EPRI - Assess Transmission and Distribution Service Quality and Reliability Performance Indicators (1009307)

15. DOE - Unlock the Value In the System Load

16. DOE - Demonstrating DER In Connecticut & Northeast Electric Market

17. DOE - Consensus In Values, Communications, & Technologies Enabling Interoperability

18. DOE - Implementing IEEE1547 As A Regional Interconnection Standard

19. DOE - Grid 2030: A Vision for the Future

20. NEETRAC - Overall Organization

21. NEETRAC - Electric System Automation Philosophy

22. EPRI - Enhancing Product Mix Software Capabilities (TO-111539)

23. EPRI - Measuring Demand Response to Market Prices (1000833)

24. PSERC - Costing and Pricing of Ancillary Services (M-1)

25. PSERC - Market Interactions and Market Power (M-3)

26. PSERC - Market Redesign: Incorporating The Lessons Learned From Actual Experiences For Enhancing Market Design (M-4)

27. PSERC - Structuring Electricity Markets for Demand Responsiveness: Experiments on Efficiency and Operational Consequences (M-7)

28. CERTS - Market Mechanisms for Reliability Management

29. Oak Ridge National Labs – ORNL - Ancillary Services Project

Appendix D: Private Sector R&D

The activity for distribution R&D has been relatively minimal in recent years. Utilities have been focused on cost cutting, are capital intensive, have extensive infrastructure that is relatively low-tech, and have little regulatory incentive to adopt new technology. Most of the new developments for distribution are being done by manufacturers in the private sector. Their Initiative to develop features, functionality and new technologies are usually initiated by:

1) A customer defining a need and committing to purchase based upon successful development, or
2) Anticipation that unique functionality added to an existing product would provide increased market share,
3) A mechanism to reduce cost or increase product life to exceed technology offered by the competition,
4) Achieve operational efficiencies,
5) Respond to new regulatory mandates or drivers like:
    a. Tax credits (i.e., spurring wind generation impacting technology for dynamic VAR support)
    b. Reliability mandates (driving technologies to avoid outages or reduce the length of outage),
6) Challenges to secure right-of-way,
7) Lack of space for construction (drives a smaller footprint),
8) Pressures to accomplish more with few people / reduced expertise (Get data and feedback remotely),
9) Power factor correction mandates,
10) Environmental (i.e., stainless steel is applicable to corrosive, offshore environment)
11) Protection schemes and safety (i.e., avoid closing into a fault)
12) Target and minimize maintenance (battery free, report by exception)

North American companies are doing the bulk of private sector Distribution System R&D. Distribution R&D is usually is done in the form of incremental change to an existing product line. Because the development time is so long and expensive, entry to market is difficult. Also, little is done on step-change research for distribution because of the backward compatibility the new product has to have with existing product and infrastructure. Entities like IEEE Power Engineering Society provide a mechanism for utilities, manufactures and academics to define standards to ensure the industry is in agreement and product compatibility and adaptability to existing systems. Some inter-operability developments are being done by manufactures which is usually customer funded and specified.

Finally, private companies are not forthcoming regarding their developments since they lose or gain competitive advantage by their ability to bring differentiated features, functions and benefits to the market place. Given the dynamic -- that specifics about technology development are not available - only the general information about manufacturing activity can be provided. Most of the manufacturing activity is oriented toward development rather than research since the addition of features and functionality provide competitive advantage and increased sales.

In recent years, many utilities have digitized their paper distribution maps and are now utilizing Geographic Information Systems (GIS). GIS systems have typically represented the static state of the distribution system. Applications are in development to utilize the platform for more efficient planning, engineering design, and developing targeted maintenance efforts. There are also development efforts to increase the interoperability of the GIS information with real-time operating systems. By moving in this direction, the GIS can be updated to represent the present configuration and forecasted equipment overloads. GIS is also being integrated with automated meter reading data and call center data to more quickly identify fault locations and most efficiently dispatch for power restoration.

There are many technologies available for automating meters. Manufacturers continue to develop new technologies for communications and cost-reduction. Efforts are also underway to consolidate Automated Meter Reading (AMR) data from various acquisition systems to reduce the integration challenges for utilities. Automated metering data is useful for distribution entities for load profiling, validating load management impacts, and efficient outage response; manufacturers are developing associated applications.

Manufacturers are also working on mobile computing. As-built information, maintenance data, design sketches and a host of additional data can be loaded into rugged mobile field devices and downloaded onto central computers. Mobile computing can also offer maps, and additional information for field crews to increase their efficiency. Manufacturers are developing more rugged hardware, increased interoperability, enhanced security features and applications that further leverage the existing software/hardware.

Since a great deal of savings can result from increase crew productivity, the ability to dispatch most-efficiently is an area where manufactures are developing technology. Technologies integrate the needs/location of field work, with crew locations, vehicle locations, crew competencies, and material availability.

The distribution system includes millions of points that hold potential for telemetry. Some of the telemetry needs are real-time and others are occasional. Manufactures are working on secure, cost effective communications; usually associated with a particular application (like automated switching) utilizing proprietary protocols.

From the hardware perspective, manufacturers are applying electronics to traditional equipment for more sophisticated control as well as the capability to interrogate information about the equipment remotely. With the application of electronics, efforts to increase battery life and perform self-diagnosis are of interest; the amount of manufacturing activity in this area is unknown.

Manufacturers are always finding ways to decrease the cost and increase performance by using different paints, dielectrics and other materials. The result for example is longer lasting cable, more durable enclosures, and a delayed rate of pole decay.

Reclosers have been increasing in functionality. One manufacturer is working on a battery free device that can be control with a PDA. Manufacturers are also working together to develop equipment interoperability. For example, work is being performed to have distribution switches and reclosers interoperate with substation relays. Relays are also under-development which uses light to initiate and mitigate the impacts from arc-flash and improve safety conditions. Relays are also including scrambler functionality for increased security and time stamping for synchronous phasing. Another manufacturer development is a molded switch with single-phase switching. The totally encapsulated device has no gas, nor pressure, and therefore minimal contamination. There are also efforts to improved protection and control devices thereby expanding SCADA capabilities. An award-winning application of distribution automation and interoperability is at ENMAX in Calgary, Canada which won the Tech Advantage project of the year in 2005.

Promotion of new developments

Manufacturers typically announce new developments at the IEEE T&D show and at Distributech. New developments are kept confidential until companies are prepared to take them to market. Another place to identify new developments is in the industry trade magazines. Examples of literature of relatively newly released product are included. The final place for investigation is patents; however, some apply for the patent right before shipping; so work could be commencing on the subject for 2 or more years before the patent application if filed

Product enhancements are typically implemented to address field-problems. New concepts are usually customer driven. This is a high reliability business and equipment needs to last for 30 and more years. The cost to take a new product through R&D is typically $5 – $10M.

Time to Market

It typically takes 2 -3 years to take new product through R&D. Once the product had been developed, it can take another 10 years to educate the marketplace to the point where they are readily purchasing the product.

Appendix E: International R&D

ELECTRIC DISTRIBUTION SYSTEM:

INTERNATIONAL RESEARCH & DEVELOPMENT ACTIVITIES

The major foreign electric utilities are participating in EPRI Power Delivery and Markets R&D program. The EPRI membership list in the 2004 Annual Report included forty-four electric distribution companies from twenty-two different countries.

Of the twenty-two countries, eighteen have functioning chapters of the IEEE/Power Engineering Society (PES). This means that the engineers at the companies in these countries have access to the standards activities and technical information publications that are available in North America.

*Argentina	*Brazil	*Canada	*China
*Columbia	*France1	*Ireland	*Italy1
*Japan1	*Korea1	*Malaysia	Namibia
*New Zealand	*Norway	Romania	*Singapore
*South Africa 1	*Spain	Taiwan	*Thailand
*United Kingdom	*Venezuela		

(*Countries w/ active PES Chapters, 1 – Countries in the top ten rated by electric sales.)

There are more foreign companies that participate in the generation and environmental programs at EPRI.

Two of the largest electric utilities that participate in EPRI are Electricite` de France (EDF) and Eskom of South Africa. EDF is number two in the world in energy sales with 525.2 TWh and Eskom is number nine with 188.0 TWh in energy sales. Both participate in EPRI and have active PES Chapters in their respective countries. Russia is number one in the world with 617.4 TWh in sales.

EDF

EDF participates in EPRI as well as the Edison Electric Institute Distribution Committee. Mr. Benoit Dreux, a Vice President at EDF has an office in Washington D.C. He is very active in the electric utility industry activities in North America. Mr. Richard Schomberg represents EDF at EPRI on a full time basis. In addition, EDF is represented on the Board of Directors and the Research Advisory Committee at EPRI.

EPRI Board of Directors – Franqois Ailleret

EPRI Research Advisory Committee – Jacques Joreaire

The EDF web page describes its relationship with EPRI.

The Electric Power Research Institute (EPRI), which has worked with EDF for many years, is a non-profit making organization, which federates R&D for American electricity companies. Early in 2003, the two parties renewed their nuclear energy partnership for an additional 4 years.

The EDF web page describes the focus and direction of R&D at EDF. One of their specific focus areas is the distribution and transmission grid.

Fields of research and modes of testing

EDF R&D has organized its activity into three research fields and two cross sectional fields. Generation, grid, commercial competitiveness, environment and information technology are the focus of engineers and researchers who employ several modes of testing.

Generation

The three traditional branches of electricity generation.

Commercial development

Proposing new services and improving their quality to satisfy users.

Grid

Improving the distribution and transmission grid is a priority.

Environment

Nearly 15 % of the annual R&D budget is spent on the environment.

Information technology

Evaluating information technology to provide new professional and managerial tools for the EDF Group.

EDF puts a lot of effort into the generation segment of the electric system. EDF R&D, the CNRS/Ecole Nationale Supérieure de Chimie de Paris (ENSCP) launched a research and development program in 1998 to develop photovoltaic thin layers by electrolysis.
Initially concentrating on cell formation, the program was extended in 2000 and given an industrial objective. Saint Gobain Research combined with EDF and the CNRS/ENSCP to develop a suitable glass substrate. The program CISEL for Electrodeposited Copper Indium Selenium, receives financial support from the French Agency for Environment and Energy Management (ADEME).

The second area is nuclear energy. EDF and its partners in nuclear energy research are working to find solutions for sustainable development. The reactors of the future (new generations of water reactors, HTR, reactors à sel fondus…) will be increasingly safer and supply ever-cleaner energy. This optimizing of energy provision is essential in today’s context of continually increasing demand.

Eskom

The greatest challenge facing Eskom at this time is providing electric service to all the remote villages and farms in the country. They have a mandate to wire the country similar to what the Rural Electrification Act did in the USA during the 1930’s.

Based on information contained on its web page, the focus of R&D at Eskom is on end use efficiency of industrial customers. They have an in-house test lab to evaluate the efficiency of various customer electrical products and processes. One of their largest industrial customers is Alcan Aluminum.

The Eskom Foundation has a tie to the Council for Scientific and Industrial Research (CSIR) in Pretoria, South Africa. Recently, South Africa, Botswana and Zimbabwe have joined together to develop new technologies in Africa. The following information for the Regional Research Alliance web page outlines the areas of research.

The Regional Research Alliance (RRA) represents the combined knowledge and skills of three leading knowledge intensive technology research and development organizations from the southern Africa region. These are:

Botswana Technology Centre (BOTEC)

CSIR, South Africa

Scientific and Industrial Research and Development Centre (SIRDC), Zimbabwe

The Alliance will focus on undertaking projects of high impact and relevance to the region for the benefit of all.

Areas for initial focus have been agreed by the members of the Alliance and technical experts will develop business plans to determine the way forward.

One of the focus areas is energy.

Energy Vision: To be the leading energy group for the development of the Region and the rest of Africa through offering quality energy products and services

The other two areas of research are 1.) water and food security and 2.) building construction and infrastructure. The details for the research have yet to be worked out. The last meeting of the alliance was in April 2005. To date, there is no additional information available on the web.

Broadband Power Line Communications

Broadband Power Line (BPL) Communications development work was done in Europe. It is largely deployed and has proven beneficial. Efforts are underway to implement this technology in North America.

The greatest challenge and most expense associated with the BPL technology is getting the signal past the distribution line transformer. The BPL technology has been successful on the European style electric system due to its configuration. Because of relatively low electric energy consumption by individual customers and the high density of customers, many customers can be served from one distribution line transformer. Therefore, the expense of getting the BPL signal past the transformer can be shared among many end use customers.

The electric distribution system in North America has fewer customers per line transformer. As a result, the expense of getting the BPL signal past the distribution line transformer has to be support by just a few end users. The technology will work on the North American style distribution system but it is very expensive.

NETHERLANDS DISTRIBUTED GENERATION

The Netherlands has an advanced liberalized market where DG is well established principally because government policies have favored CHP and renewable energy sources. However, the general policy thrust of the Dutch government is to avoid using favorable grid policies or tariffs to subsidize the development of these technologies, relying instead on other methods.

The substantial Dutch experience with DG has had some important advantages. Unlike the situation in the US, interconnection rules in the Netherlands are not a problem. Market rules were adjusted soon after they were introduced, so that CHP producers could more accurately predict how much electricity they would supply to the grid. Power parks have been established where the main power producer is the only customer with a direct connection to the grid. But CHP producers have faced difficulties because of rising gas prices and falling electricity prices. To help them cope, the Dutch Government has increased direct subsidies to producers and has encouraged distribution companies to ensure that the network value of DG is appropriately reflected in tariffs.

CANADIAN UTILITY RESEARCH & DEVELOPMENT

The two major electric utilities in Canada have laboratory facilities that address distribution systems issues. However, they do no appear to have a strong focus on Research and Development. Their concentration seems to be on finding innovative solutions to problems encountered on the distribution system. The solutions may come from research around the equipment or material causing the difficulty.

BC Hydro Powertech

Powertech Labs Inc provides testing, consulting and research services to the electric and natural gas industries, their customers and suppliers. The Powertech facility in Surrey, B.C. has 18 laboratories and approximately 80 professional engineers, scientists and technologists. Powertech has a wide range of expertise and facilities in electrical engineering, power systems stability, materials engineering and applied chemistry. This provides a one-stop source of analysis, testing and consulting services, not only for power utility customers in North America and overseas, but also for a growing list of clients in other industries who use similar technologies.

Powertech solves technical problems with power equipment and systems throughout their life cycle, from the design stage through service life, to disposal and re-use.

Many technical issues are complex, requiring knowledge across several disciplines for complete assessment and remediation. In a single facility Powertech offers electrical, chemical, environmental, gas technologies, mechanical, metallurgical, materials, civil and structural engineering expertise gained over years of research and testing.

The resulting solutions to technical problems are practical, timely, and cost-effective.

The company is organized around seven distinct business units: Power System Studies; Electrical Technologies; Power Engineering Labs; Civil Infrastructures and Alternative Energy Technologies; Gas Systems Engineering; Materials Engineering and Applied Chemistry.

The Powertech facility in Surrey, BC has 18 labs and approximately 80 professional engineers, scientists and technologists. Through resource sharing, they form a network that provides a one-stop analysis service not only for power utility customers but also for a growing list of industries such as gas transmission and distribution, transportation, and pulp and paper.

Hydro Quebec Research Institute

Power Quality Analyzer (Mini AQO)

The Mini-AQO power quality analyzer was developed by Hydro-Québec's research institute for Hydro-Québec Distribution.

Is electric power a service or a product? There is a growing trend in the electricity industry to consider power as a product. As such, this product must not only be defined, but power-quality standards and criteria must also be established. Modern equipment featuring electronic components and sensitive microprocessors is exposed to voltage disturbances: industrial motors, hospital scanners, personal computers, etc. Consequently, power quality is a factor in customer satisfaction.

The power quality analyzer is the result of a vast project aimed at developing a Canadian power quality measurement protocol. This tool enables a better definition of the electricity product.
Processes an enormous quantity of data in real time.

Simultaneously measures four levels of voltage and current, along with 80 power quality factors. Operates under the Windows operating system.

Polymer Additive for Wood Poles:

Polymer-based additive was developed by Hydro-Québec's research institute for Hydro-Québec Distribution.
In use since 2000, this product is marketed by Arch Wood Protection

Hydro-Québec Distribution uses about 2.5 million wooden poles. To protect them from rot and insect damage, treatment previously consisted of injecting them with oil to which PCP (pentachlorophenol) was added, imparting a brown color to the poles. In the early 1990s, some government agencies were thinking about restricting the use of PCP, and thus Hydro-Québec turned to other wood preservation options.

A water-soluble preservative, chromated copper arsenate (CCA) turns wooden poles green. Poles thus treated tend to harden, thereby making them difficult for line workers to climb. In fact, the climbers worn by the workers are not able to penetrate into the wood as effectively on these hard poles. The polymer added to the CCA preservative makes the wood poles softer and proves to be a novel solution to the problem of pole hardness. This polymer improves pole climbability and does not contain oil nor emit any odor.

Infrared Thermograph Diagnostics Services:

Hydro-Québec's research institute developed the software for Hydro-Québec Distribution.

In use since 2001, this technology is a true expert system for the inspection of the underground distribution system.

The maintenance program for the underground distribution system requires regular equipment inspection and analysis. The presence of high-voltage cables requires workers to exercise extra precaution by using inspection methods such as infrared thermography. This technique uses an infrared camera to detect abnormal heat loss from cable joints. The effectiveness of thermography was, however, compromised by the absence of an accurate method for processing and analyzing measurement results.

The development of the infrared thermographic diagnostic tool has made it possible to determine the condition of cable joints and to diagnose anomalies using measurements performed with an infrared camera. This software indicates whether it is safe for workers to go down into a manhole.

Conclusion: The greater part of collaborative and public Research & Development focused on the electric distribution system is being done in North America.